

GEORGIA INSTITUTE OF TECHNOLOGY
SCHOOL OF CHEMISTRY AND BIOCHEMISTRY
SAFETY MANUAL

In the event of an emergency or lab accident, click below for
FIRST AID RESPONSE AND TRANSPORTATION POLICY
PROCEDURE

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SAFETY MANUAL

GEORGIA INSTITUTE OF TECHNOLOGY

SCHOOL OF CHEMISTRY AND BIOCHEMISTRY

FIRST AID RESPONSE AND TRANSPORTATION POLICY PROCEDURE

If a person is injured or becomes seriously ill on campus:

Notify the Georgia Tech police department (ext. 4-2500 or 404-894-2500)

The number is posted on the doors for research laboratories and teaching laboratories.

The caller (you) should be able to provide the dispatcher with some basic information:

- **Location, e.g. Boggs, second floor, room 2-47**
- **Nature or kind of injury or illness**
- **Is victim conscious or unconscious?**
- **Should an ambulance be called?**

1. If the caller can provide that information, the dispatcher will send an officer to the scene and call for an ambulance immediately if one is requested.
2. If the caller cannot provide that information, the dispatcher will send an officer who, upon arrival, will make an assessment of the situation, provide first aid to the victim and request an ambulance at the officer's discretion.
3. If the person can be transported in the police unit, the officer will provide that transportation.

INJURIES - EMERGENCY TREATMENT

The emergency response team will decide either of the following treatments.

1. Emergency treatment for work related injuries to faculty, staff, and students may be obtained from the nearest hospital emergency room (normally not the campus infirmary).
2. In some cases emergency treatment may be provided at the campus infirmary.

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PROCEDURE FOR REPORTING INJURIES, ACCIDENTS, HAZARDS, OR HAZARDOUS PRACTICES

Financial coverage for work related injuries are handled through the state worker's compensation unit insurance and all follow-up care after the initial emergency treatment.

There are certain reports which should be filled out after any accident whether or not an injury has occurred.

1. A person receiving an injury (no matter how trivial it may seem) shall report this without delay to the Research Director or Teaching Laboratory coordinator, if possible, or see that he or she is advised. The person notified of the injury shall be responsible for seeing to it that written reports are filled out by the injured and shall set any accident preventative measures in motion at once.
2. The necessary written reports are as follows:
 - a. For any accident whether or not an injury occurs, the person involved in the accident must fill out a School Accident form at

<http://www.chemistry.gatech.edu/docs/Chemistry-Accident-Incident-Report-Sheet.pdf>

Alternately, the form may be obtained from the Chairman of the Safety Committee or from the Main Office. The form will be submitted to the Research Director for additional comments. Copies of the completed report should be turned in to the Chair, School of chemistry and Biochemistry and Chairman of the Safety Committee. The reporting of accidents occurring in the undergraduate teaching laboratories will normally be the responsibility of the Teaching Assistant or Teaching Laboratory coordinator in charge of the laboratory.

- b. For work-related injuries, there is a Worker's Compensation Claim which must be completed by the supervisor of the injured person. The procedure is included in the following OHR website.

<http://www.admin-fin.gatech.edu/human/benefits/061100.html>

This claim is for the individual's protection, since insurance payments may not be issued if this form is not filed. The claim should be filed the day of the accident (within 24 hours) unless this is prevented by the seriousness of the injury. The injured person's supervisor (the Research Director or Teaching Laboratory Coordinator) reports the claim as indicated below.

Supervisors should call TeleClaim (toll free 1-877-656-7475, 24 hours a day, 7 days a week) to report injuries within 24 hours of an accident. Reporting should be delayed only long enough for the supervisor to take the employee to the doctor. ***Claims may only be reported by a supervisor. Employees can not call in their own claims.***

As soon as possible after the accident call with the following information:

- Name and Address of Injured Employee
- Name and Address of Employing Agency
- Social Security Number of Injured Employee

- Age and Sex of Injured Employee
- Date & Time of Accident
- Description of Accident (how, where, why)
- Type of Injury (cut, scrape, burn, etc.)
- Exact Part of Body Injured
- Place of Occurrence
- Full Time / Part Time Employee
- Hourly / Weekly / Monthly Wage
- Date of Hire
- Witnesses (Name and Telephone Number)
- Name and Address of Physician / Hospital
- Has Injured Employee Returned to Work?
- Anticipated length of disability
- Basic Job Duties
- Description of Physical Requirements of Job
- Supervisor's Name and Telephone Number

- c. In addition, any appropriate health insurance forms for any health plan that the individual is covered by will need to be filled out.
3. Accidents (non-injury), hazards, and hazardous practices must also be promptly reported by the observers of them to the Research Director or Safety Committee. In the case of hazards or hazardous practices which involve the facilities or housekeeping of any particular laboratory, the person responsible for the area should be notified.

It may appear that some accidents, hazards, and hazardous practices are of such a trivial nature that no report seems necessary. The point to be remembered is: Will a report of the accident or hazard be of service in detecting and eliminating an unsafe condition?

4. In the case of serious accidents and accidents of obscure origin, none of the evidence should be disturbed until an investigation is made by the proper authorities. Naturally, all steps necessary for protection of personnel take precedence over preservation of evidence.

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INTRODUCTION

The Safety Manual has been revised and updated with the objective of providing workers in the School of Chemistry with information on laboratory safety procedures and procedures for handling hazardous chemicals. This manual does not cover all conceivable safety requirements which may be necessary when working with specific chemicals or carrying out specialized procedures. Each research worker is responsible for consulting other sources before undertaking any unusual operation which is likely to have safety hazards associated with it. One important source of information on chemical hazards are the material safety data sheets ([MSDS](#)) which are available on-line for a large number of compounds in the chemistry stockroom.

Due to Georgia Tech's status as a State Agency we are not regulated by OSHA. However, GT uses OSHA Standards as guidelines. GT considers these “Best Management Practices”. Please see the U.S. Department of Labor Occupational Safety & Health Administration

06. [OSHA Laboratory Standard 1910.1450](#).

While the entire manual should be studied in detail, please pay special attention to the following parts: The [General Safety Rules](#) (you may wish to make a copy of these simple rules and post them in the Laboratories); [The Housekeeping Rules](#) (Violation of these and other rules will be noted when safety inspections are made); [Procedures for Reporting Injuries, Accidents, Hazards, or Hazardous Practices](#) (Please see to it that all necessary forms are filled out and turned in promptly); [Building Evacuation in Case of Emergency](#) ; [First Aid](#) ; and [Reporting Accidents to Campus Police](#) (Be completely familiar with the procedure for reporting an accident).

The Safety Committee would appreciate written or oral suggestions for corrections, additions, or deletions to this manual for incorporation into future updates.

Safety Committee
September 1996 and December 2005

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GENERAL SAFETY RULES

(In Case of emergency, call Ext. 4--2500 or 404-894-2500)

1. Exhibit a professional attitude and apply common sense at all times.
2. In case of doubt about a procedure, or the operation of an instrument or a piece of apparatus, consult your course instructor, research director or someone who has knowledge about the equipment in question.
3. Know the location of emergency equipment, fire alarms (fires still should be reported by Calling Ext. 4-2500 or 404-894-2500 even if the alarm has been pulled), fire extinguishers, eye-wash fountains, showers, etc., and familiarize yourself thoroughly with the operation of all these items. Also call 4-4002 to inform the Chemistry Main Office in the event of fire or injury. Know the building exits which are nearest to your work place and the classrooms in which you instruct.
4. Follow good housekeeping principles at all times.
5. There should be no smoking, eating, and/or applying of cosmetics in areas where chemicals are being used. If Research Supervisors allow these activities in research laboratories, specific areas should be set aside in which these activities are permitted but in which no chemicals are allowed.
6. Shoes which cover both top and bottom of the feet should always be worn in the Chemistry Building and Annex.
7. Safety glasses should always be worn in the laboratory. Other appropriate safety attire - goggles, face shields, lab coats, aprons, and gloves - should be worn when working with dangerous chemicals and equipment.
8. Never undertake unauthorized experiments unless you have been given permission to work independently by your Research Supervisor.

9. Before starting an experiment make sure you understand its operation in detail, are aware of possible danger points, and have formulated plans to handle emergencies that may conceivably arise.
10. Before activating an instrument or starting a machine, make certain you understand how it is to be operated and what precautions are necessary for its safe operation.
11. Use approved methods for transporting chemicals and equipment in the building and for disposing of waste chemicals and refuse. This includes safety carriers for bottles of concentrated acids and bases.
12. All laboratory workers should wash their hands thoroughly to remove any chemicals before leaving the laboratory for whatever purpose.

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I. SAFETY RULES

A. Responsibility Defined

1. The overall responsibility for the enforcement of all safety regulations rests with the Director of the School of Chemistry and Biochemistry. The Director may appoint a Safety Committee (or specific individuals) to assist in the discharge of this responsibility.
2. The Research Directors have the primary responsibility of seeing to it that those individuals working under their direction follow the School of Chemistry and Biochemistry Safety Rules, and for establishing any additional safety rules which may be deemed necessary.
3. The Faculty member in charge of any teaching laboratory has the responsibility for the enforcement of safety rules in that laboratory and for setting hours other than regularly scheduled hours when the laboratory may be used.
4. Laboratory workers or other workers have the responsibility of performing their assigned duties safely.
5. The names and telephone numbers of all knowledgeable persons in a laboratory who can be contacted in case of emergency should be posted in the laboratory door's window.

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B. Housekeeping

1. It is the basic responsibility of all workers to follow good housekeeping practices in their specific working area (s) and to take general responsibility for the room (s) in which this working area (s) is located.

2. The overall responsibility for the housekeeping in each laboratory rests with the person in charge. It is that person's job to see that all persons working in the laboratory area keep the working space in good order, and that unsafe conditions in the working space and utilities are reported and corrected.

It is the specific duty of the Research Director to see that excessive amounts of chemicals and equipment do not accumulate in the laboratory.

The Storekeeper is responsible for housekeeping in the stockroom and storage sheds.

3. Some general and specific housekeeping rules are:

- a. Keep benches, dry boxes, and hoods neat and orderly. Hoods in which experiments are being performed should never be used for storage.
- b. Use bench drawers for storing equipment.
- c. Do not allow excess quantities of chemicals or equipment to accumulate in the laboratory. Monthly housecleaning should result in the disposal of unnecessary chemicals, particularly hazardous ones. See [Section III-D](#) for appropriate procedures for return or disposal of chemicals and equipment.
- d. Keep apparatus, containers, furniture, etc., in their appropriate places so that aisles are not cluttered; especially make sure that the emergency exit to the chase is not blocked. No glass containers should ever be left on the floor.
- e. All cylinders containing compressed gasses must be secured at all times and capped when not in use. Transport cylinders only in the appropriate manner. For handling cylinders see [Section III-E](#).
- f. Make sure that electrical wires and gas or water conducting lines are not placed on the floor (unless appropriately bridged) or hung so low as to endanger persons passing under them. Light fixtures are **NOT** to be employed as supports for wires and tubing!

- g. Make sure that all motor belts (especially pumps) have guards.
- h. Glass windows in laboratory doors should not be covered. Emergency notification cards taped to the inside of the windows are acceptable. A removable covering may be utilized when the laboratory is to be used as a reduced lighting environment. These covers should be promptly removed when experiments are completed.

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C. Personal Protection

1. General Attire. Shoes which protect both the bottom and the top of the feet are to be worn at all times in the Chemistry Building and Annex. Do not wear loose clothing that may knock bottles off benches or get caught in apparatus or moving machinery parts. Restrain long hair. Students should avoid wearing skimpy clothing (e.g., shorts, halters, etc.) in the laboratory. Such clothing offers little or no protection to the skin from chemical splashes or spills.
2. Eye Protection. Eye protection (laboratory safety glasses as a minimum) must be worn when any experimental and mechanical work is being conducted or when one is in the proximity of such activity. (When deskwork is being conducted exclusively, safety glasses are not required, but they should be kept on if one is going back and forth between experimental and deskwork.) Certain operations require the use of additional eye protection. Special glasses, goggles, and face shields should be worn when operations are being conducted which offer unusual danger to the eyes.

Contact lenses may be worn in chemical laboratories. Contact lenses are not eye protective devices. Safety glasses with side shields or safety goggles must be worn in the laboratory. NIOSH recommends: "In the event of a chemical exposure, begin eye irrigation immediately and remove contact lenses as soon as practical. Do not delay irrigation while waiting for contact lens removal." Should an eye-splash occur while wearing contact lenses, the victim should go directly to the eyewash and begin rinsing. Do NOT waste time trying to remove the contact. Let the eyewash water remove the lenses and irritant for you.

Prescription glasses can be worn in place of laboratory safety glasses only if they are constructed from tempered safety glass and are equipped with side shields. Safety goggles or face shields must be worn over normal or non-safety corrective glasses.

It is recommended by the safety committee that all groups make visitor safety glasses available at either the entrance to their lab complex, in individual labs or in a convenient central location.

3. Skin Protection. Wear a lab coat with the sleeves rolled down and use an apron, especially when working with corrosive chemicals and when undertaking experiments where splattering is possible. Use a safety shield where appropriate.

Protect your hands and arms by wearing gloves. These come fabricated from a variety of materials and the appropriate choice will depend on the chemicals against which protection is sought. Consult Section III-J for data on material selection.

Gloves should not be worn outside of the working laboratory to avoid contamination of door handles and other surfaces.

4. Respiratory Protection. The basic and best protection is to make sure that the lab is well ventilated. Check ventilation periodically. Conduct all operations which generate hazardous and/or noxious fumes in a hood. Remember, however, that a hood can protect only if operated in the appropriate manner. Familiarize yourself thoroughly with the information on hoods in Section III-K.

In exceptional cases, use of a respirator may be required. This should be discussed with the Research Supervisor.

5. Reproductive Hazards - Chemists who are planning to have families should be aware of the potential hazards posed by exposure to mutagenic and teratogenic chemicals, radioactive materials, and ionizing radiation. The School of Chemistry and Biochemistry will be happy to co-operate with the physicians of those concerned to develop plans for minimizing these dangers.

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D. Eating, Smoking, and Applying Cosmetics in Working Areas

1. Smoking is strictly prohibited throughout the building (s)..
2. Eating and/or drinking in the laboratory is prohibited unless permission is obtained from the person having primary responsibility for the laboratory. If these activities are permitted in the laboratory, specific areas should be set aside for them and no chemicals should be allowed in those areas.

3. Storage of food or beverages is prohibited in the laboratories or in the laboratory refrigerators. Store food only in facilities approved for this purpose; do not use facilities designated for chemical storage. Microwaves and refrigerators designated for food should be clearly marked for non-chemical use.
4. Cosmetics should not be stored or applied in areas where chemicals are being used.
5. All laboratory workers should wash their hands thoroughly before eating, smoking, applying cosmetics, or leaving the laboratory for whatever purpose.

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E. Working after Regular Hours

1. Under normal conditions, at least two persons are required on each floor if laboratory work is to be performed after the usual working hours. Arrangements shall be made between individuals for crosschecking periodically. It is permissible for a person to work alone only when doing desk work.
2. For unusual experimental conditions special rules may have to be formulated if work is to be done after the usual working hours. For example, two persons may be required in one room if an unusually hazardous operation such as the use of HCN is in progress. The person in charge of the laboratory has responsibility for determining whether or not the normal rules are adequate, and for specifying additional coverage if deemed necessary.

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F. Specific Rules for Lab Operation

1. Keep exposure to all chemicals to a minimum. Form the habit of washing your hands and face frequently when handling chemicals. Always wash your hands before eating or smoking.
2. Never use mouth suction to fill pipets. Apply vacuum from an aspirator bulb or vacuum line.
3. Do not start a siphon by mouth.
4. Use care in handling all hot items. Protect your hands with protective gloves.

5. Avoid moving large glass vessels of any type when they are filled with liquids. If transportation is necessary, be sure that appropriate safety precautions are taken to prevent breakage and spillage and that clean-up equipment is ready in case of mishap.
6. Working with glassware, boring holes into stoppers and inserting glass tubes into them can present hazards. Consult Section I-M on how to conduct these operations safely.
7. Use boiling stones, sticks, or some other ebullator when performing distillation. However, do not add any of these to a liquid which is already hot.
8. When volatile solvents are shaken in separatory funnels, considerable pressure may develop. Release the pressure by frequent venting. This is accomplished by inverting the funnel and opening the stopcock briefly while making sure to point the funnel away from your face.
9. Be cautious when smelling compounds to examine them. Never hold the nose directly over the container. Rather waft a little bit of atmosphere from above the container towards the nose with your hand. Before smelling, inhale deeply so that air can be expelled immediately in case the fumes are irritating.
10. There is an upper limit to the size or weight of a load that can be safely lifted or transported by one person. Get assistance when your personal limit is approached. Remember, lift with your legs, not with your back.
11. When borrowing equipment, talk with the owner or person in charge of it. Get information as to the correct operation, any shortcomings or defects, and possible contaminations.

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G. Operations Hazards

1. All new operations and equipment or significant changes in operations or equipment should be approved by the person in charge of the laboratory.
2. Hazardous operations must be appropriately labeled and guarded to prevent injury to others. Nearby workers should be warned before a hazardous operation is started and warning signs should be posted at all entrances. Examples of such operations include:
 - a. Performing reactions or procedures that use highly reactive or toxic compounds in appreciable quantities (i.e. more than 0.1 mole). Examples would include:

1. HCN (or cyanide derivatives), phosgene, carbon monoxide, or hydrogen fluoride.
 2. alkali metals or organometallic reagents: e.g. derivatives of Li, Na, K, Al, B, or Mg.
 3. volatile metal compounds (metal carbonyls, dimethylmercury, etc.)
 4. toxic heavy metal compounds (e.g. Hg, Os, Pb, Tl)
 5. catalytic hydrogenation or other procedures using hydrogen gas.
- b. Performing reactions or procedures that use 1.0 g or more of potentially explosive compounds. Examples would include:
1. peroxides
 2. azides
 3. diazo compounds (e.g. diazomethane)
 4. ozonolysis to form ozonides and subsequent transformation of these ozonides.
 5. any reaction being performed under pressure (sealed tube, pressure bottle, autoclave).
- c. Use of any other material suspected to be (1) toxic; (2) explosive; (3) mutagenic or teratogenic (4) highly inflammable. (The current edition of the Merck Index can serve as a brief, readily available guide to chemical hazards.) Refer to the books in the Safety Section of the Chemistry Reading Room for more detailed information. The book, 'Prudent Practices for Handling Hazardous Chemicals in Laboratories,' is especially helpful since detailed handling procedures are provided.) Finally, material safety data sheets ([MSDS](#)) are available in the Chemistry Stockroom and should always be consulted for dangerous compounds.
- d. Purification of anhydrous solvents in quantities of 500 mL or more. This is especially true for solvents refluxed over or distilled from a reactive metal hydride such as Lithium Aluminum Hydride.
- e. Use of known, potent carcinogenic compounds in quantities of the order of 1.0 g or more. Some common examples include vinyl chloride, methyl chloromethyl ether (a common by-product in many chloromethylation procedures), N-nitrosodimethylamine, and ethylenimine.
- f. Performing any reaction or procedure (e.g. large scale extraction) where the quantity of flammable organic solvent being used is 1000 mL or more.

- g. Use of any apparatus involving a laser or other intense light source (e.g. UV lamps for preparative work) where eye protection would normally be advisable.
- 3. Unattended Operations. It is essential that all unattended operations be designed to be "fail safe". Remember that every utility - cooling water, electricity, compressed air, natural gas, ventilation and tanked gas - is subject to failure without warning. Plan for such emergencies. Devices which will cut off heating equipment when the water pressure drops are available. Ensure that all water hoses are properly secured and in good operating condition.
- 4. Generalizations
 - a. When diluting acids, **ALWAYS** pour the acid into water, slowly and carefully, and not the reverse.
 - b. Never carry out a reaction in a closed system or heat an apparatus which is a closed system unless the system is designed to withstand the pressure which may develop. If it is undesirable that a reaction mixture be open to the atmosphere, consider the use of a mercury bubbler and nitrogen purge to ensure that a pressure build-up doesn't occur.
 - c. In case a new reaction is attempted, always try it first on a small scale. However, you should recognize that when a reaction is scaled up, certain safety problems may be amplified drastically; be prepared for such eventualities.
 - d. In case of doubt, always assume the worst will happen and carry out the reaction in the hood with sashes closed and an explosion shield in place. (The hood sashes are made of laminated safety glass, but they do not provide sufficient protection from powerful explosions.) Put yourself into a position where minimum exposure is guaranteed and inform other persons in the room about the situation. Never undertake such experiments when alone!

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H. Machinery and Equipment Hazards

- 1. Be thoroughly familiar with machinery and equipment before attempting to operate it.
- 2. Equipment must not be operated until moving parts, such as shaft, couplings, gear trains, belt drives, etc., have been guarded.

3. Sometimes drill bits, saw teeth, grinding wheels, and shear points cannot be guarded. Be especially attentive while using machines having such hazards.
4. Gloves, ties, loose clothing, and long hair can be "caught" by rotating machine parts. Do not expose yourself to injury by ignoring such hazards. Restrain long hair and loose clothing.

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I. Flame Hazards

1. Persons assigned to a laboratory may use an open flame in this laboratory, providing the following rules are scrupulously observed:
 - a. Use the open flame only when absolute necessary and only for the period of time it is actually needed.
 - b. Check with all other occupants of the room before using an open flame.
 - c. Prior to lighting the flame, remove all flammable liquids from the area where the flame is to be used. Check all containers of flammable liquids in the room to be sure that they are sealed.
 - d. See [Section III F](#) on the handling of flammable materials and [Section III I](#) on the handling of pyrophoric materials.

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J. Vacuum Hazards

1. Any glass equipment operated under vacuum can collapse violently, causing a shower of flying glass. For this reason, appropriate shielding must be used during these operations. For suction filtrations, always use the thick-walled flat-bottom flasks specifically designed to withstand vacuum. Even these are dangerous if cracked or otherwise weakened. Ordinary Erlenmeyer flasks larger than the 50 ml size should never be subjected to vacuum. Always inspect the glassware for defects before using in a system that will be placed under vacuum.
2. Unless they are stored or equipped with metal mesh cages, protect vacuum desiccators or bottles by application of several strips of adhesive tape.
3. Dewar flasks must be shielded or wrapped with electrical or cloth tape.
4. Cold traps of adequate size and temperature to catch all condensable vapors should be inserted between the system and the vacuum pump. A

pressure-measuring device should be installed before the cold trap. Check these cold traps frequently to guard against their becoming plugged by the material collected in them.

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K. Electrical Hazards

1. General. While all research personnel, in varying degrees, may be familiar with utilities and services, electrical repairs should be made only by authorized personnel. Electrical service lines (110 or 220 volt) can be a source of serious injury. Under certain conditions, contact with only 25 volts can cause fatalities. If there are any questions concerning the safety aspects of electrical connections, the Electronics Shop personnel will provide expert advice.
2. Required in All Laboratories
 - a. Proper grounding of all units is required.
 - b. Do not use defective or damaged wires or equipment.
 - c. Explosion-proof equipment must be used in those areas where the possibility of a flammable atmosphere exists.
 - d. Open Variacs, heat guns, and other non-explosion-proof electrical equipment should not be used around flammable materials. ALL VARIACS SHOULD BE MOUNTED OUTSIDE OF HOODS AND ON WALLS OR FRAMES ABOVE BENCH TOPS SO AS TO MINIMIZE THEIR EXPOSURE TO FLAMMABLE MATERIALS. Use proper operating procedures for devices such as Variacs, heat guns, heating mantles, oil baths, etc., and be aware of the possible dangers associated with their use.
 - e. Have connecting wires and cables arranged in appropriate positions. Do not place them on the floor (unless bridged) or so low over an aisle that normal traffic is impaired! All connections involving 110 V wiring should be mechanically secure; the use of alligator clips, etc., for making electrical connections is not permissible.
3. Precautions. Damp concrete provides a good electrical ground. Never stand on a wet floor when operating switches, Variacs, stirrers, etc. Rubber floor mats are recommended where such hazards exist.
4. Electrical Shock

- a. Report all cases of electrical shock, however minor, to your Research Director. Until the defect which caused the shock is remedied, do not attempt to use the device again.
- b. Familiarize yourself with the appropriate procedures for action in case of an electrical accident, and first aid measures for a shock victim. See [Section II](#).

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L. Radiation Hazards

In some investigations, intense light, laser beams and radioactivity are employed. These operations require thorough familiarization with the equipment, its use, and the necessary precautionary measures. Consult your Research Director for the procedures to be followed in these situations.

For persons not engaged in the work, the basic rule is to stay away from the areas marked as restricted and to obey signs on doors.

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M. Hazards Associated with the Handling of Glassware and Related Equipment

A major portion of laboratory injuries result from wounds inflicted through improper usage of ordinary glassware. Certain basic steps may be followed to prevent these injuries. One of the most important steps is to always provide hand protection, either by use of properly padded gloves or by use of heavy cloth, whenever manipulating glass tubing.

1. Inserting Glass Tubing into Rubber Equipment

- a. Be sure that the ends of the tubing are fire polished.
- b. Never try to force glass tubing into an orifice that is too small.
- c. Lubricate the tubing before insertion. Glycerin is a handy lubricant, although water or stopcock grease may also be used.

2. Removing Rubber from Glassware Connections

- a. Do not use excessive force to disconnect glass joints, rods, or tubes.
- b. Wet the glass tubing with water, and also force some water between the glass and rubber surface. If lubrication does not loosen the connection, cut the rubber away.

3. Removing Frozen Stopcock Plugs and Stoppers

- a. Avoid the use of force.
- b. Gentle tapping of a frozen stopper with another glass stopper will often loosen the stopper.
- c. Immersion of frozen stoppers into warm water may also help free the stopper.
- d. Special assistance may be obtained from the glassblower.

4. Breaking Glass Tubing

- a. Always hold the tubing inside a cloth towel near the scratch and break away from yourself. It may be necessary to wet the scratch to obtain a clean break.
- b. Always fire polish the freshly broken ends.

5. Broken Glassware and Glass Waste

- a. Intact standard taper joints from broken glassware should be washed and saved to be used in construction of new items in the Glass Shop. Broken glass should be placed in special blue plastic containers labeled "Sharps Only". Broken glass should not be placed in the waste baskets with other trash as this presents a hazardous situation for custodians.

6. Cork and Stopper Borers

Cork and stopper borers are knives and can inflict severe wounds if not handled properly. Be sure that the blade is sharp, since undue pressure may be necessary if a dull blade is used. Lubricate the area to be bored with either household oil or glycerin. Leave the borer in good condition.

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N. Procedure for Reporting Injuries, Accidents, Hazards, or Hazardous Practices

1. A person receiving an injury (no matter how trivial it may seem) shall report this without delay to the Research Director, if possible, or see that he or she is advised. The person notified of the injury shall be responsible for seeing to it that written reports are filled out by the injured and shall set any accident preventative measures in motion at once.
2. The necessary written reports are as follows:
 - a. For any accident whether or not an injury occurs, the person involved in the accident must fill out a School Accident form (<http://www.chemistry.gatech.edu/docs/Chemistry-Accident-Incident-Report-Sheet.pdf> or obtained from the Chair of the Safety Committee or from the Main Office) and submit this report to the Research Director for additional comments. The completed report should be turned in to the Chair of the School of Chemistry and Biochemistry and Chair of the Safety Committee. The reporting of accidents occurring in the undergraduate teaching laboratories will normally be the responsibility of the Teaching Assistant in charge of the laboratory.
 - b. For work-related injuries, [Worker's Compensation Claim](#) forms which must be filled out. These forms are for the individual's protection, since insurance payments may not be issued if this form is not filed. They should be filled out the day of the accident unless this is prevented by the seriousness of the injury. The form must be completed by the supervisor of the injured person.

In addition, any appropriate health insurance forms for any health plan that the individual is covered by should be filled out, especially for those people covered by the Board of Regents Health Plan. Forms are available from [GT OHR](#).

3. Accidents (non-injury), hazards, and hazardous practices must also be promptly reported by the observers of them to the Research Director or Teaching Lab Coordinator. In the case of hazards or hazardous practices which involve the facilities or housekeeping of any particular laboratory, the person responsible for the area should be notified.

It may appear that some accidents, hazards, and hazardous practices are of such a trivial nature that no report seems necessary. The point to be remembered is: Will a report of the accident or hazard be of service in detecting and eliminating an unsafe condition?

4. In the case of serious accidents and accidents of obscure origin, none of the evidence should be disturbed until an investigation is made by the proper authorities. Naturally, all steps necessary for protection of personnel take precedence over preservation of evidence.

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II. EMERGENCY PROCEDURES

A. Building Evacuation in Case of Emergency

I. It is imperative that the building be evacuated in an orderly manner and that security be maintained in case of an emergency. If the fire alarm is sounded, leave the building immediately via the nearest exit and move well away from the building exit so as not to interfere with fire fighting or rescue personnel. (If an experiment is in progress and time permits, take a few seconds to do what is necessary to shut it down or leave it in a safe operating mode. Obviously, you will have to exercise professional judgment in such situations.) If you are in the classroom (as an instructor or student), leave the building by the nearest exit. Instructors should be familiar with the exit routes for their classroom so that they can instruct their classes on the procedure for leaving the building in an orderly manner.

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B. Fires in Laboratory Areas

1. Fire Prevention. It is imperative that all possible means of fire prevention be practiced continuously. Should a fire occur, it becomes essential that it is brought under control and extinguished as soon as possible. This is possible only if all persons understand clearly their responsibilities and know fully the proper steps for handling emergencies of this type.
2. Responsibilities
 - a. The Research Directors are responsible for:
 - (1) instruction and training for their research students, technicians, and assistants in fire prevention and in proper handling of fires in the laboratory;
 - (2) making periodic inspections of their research laboratories for potential fire hazards and for correction thereof and for making sure of the availability of fire fighting equipment.
 - b. The Teaching Staff is responsible for:

- (1) instruction and training for all teaching and student assistants in the laboratories under their control;
 - (2) making periodic inspections of these laboratories for potential fire hazards and for making sure of the availability of fire fighting equipment.
 - (3) complete shut-down of all apparatus prior to evacuation for power outages.
- c. The Research and Teaching Personnel are responsible for:
- (1) fire prevention and elimination of fire hazards;
 - (2) recognizing the potential fire hazards of each laboratory operation;
 - (3) knowing the location of and proper manner of use of fire alarms and all fire fighting equipment;
 - (4) in the event of a fire, knowing whom to call for assistance.

3. Reporting Fires

- a. If it is certain that you can control the fire yourself, proceed to do so immediately.
- b. Should it be apparent that the fire is out of control or is likely to get out of control, the following is to be done:
 - (1) Sound the fire alarm so that the building can be evacuated.
 - (2) Call Campus Security (Ext. 4-2500 or 404-894-2500) immediately and report the location of the fire and, if possible, the type of fire, e.g., chemical, electrical, etc. (The Campus Police will call the Fire Department to report the fire and will escort the fire trucks to the proper location.)
 - (3) Notify the research director or the faculty member responsible for the laboratory. Should this person not be available, notify the nearest faculty member.

4. Methods of Extinguishing Fires

- a. Organic solvent fires - use dry powder or CO₂, extinguishers.
- b. Electrical fires - use dry powder or CO₂, extinguishers. (Do not use water type).

- c. Chemical fires - use dry powder A-, B-, C-type fire extinguishers for all chemical fires except active metals such as Na, K, Ca, etc., and their alkyls.
- d. Active metal and metal alkyl fires - use Met-L-X fire extinguishers on Class D (metal) fires. The extinguishers should be available in all laboratories in which active metals, metal hydrides, and/or metal alkyls are used. Vermiculite, sand, graphite, and dry salts are also effective materials for smothering metal fires.

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C. First Aid

- I. General. First aid is emergency care of a person who is injured or ill so as to prevent death or further injury, to relieve pain, and to counteract shock until medical aid can be obtained. The objectives of first aid are:
 - a. to prevent further injury, e.g., removal of victim from fire or gas area or the use of safety shower or eye fountain;
 - b. to check conditions which may endanger life, e.g., stopping blood losses, restoring breathing, or preventing or moderating shock;
 - c. to protect injuries from complication, e.g., immobilizing fractures and dislocations or protecting burns or open wounds from dirt, etc.;
 - d. to reassure and to make the patient as comfortable as possible, e.g., shock can often be lessened or even prevented and patient's strength conserved by comforting the injured. In many cases a light cover, e.g., a blanket is helpful.

2. Initiating First Aid

- a. The responsibility for first aid rests initially with the first person (s) on the accident scene. One need not be highly trained to give first aid; by all means, remain calm.
- b. Common sense should be the first aid guide for assisting after an injury. The first principle of first aid to an injured person concerns that person's life; the second principle concerns the injury.
- c. The person giving first aid in case of serious injury should:
 - (1) follow the "[First Aid Response and Transportation Policy Procedure](#)".

- (2) not move the injured person unless it is quite apparent that the person is in further danger by remaining at the present position. In such instances, move the person as little as possible and with utmost care and gentleness.

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D. Spills

1. General. Chemical spills can present serious hazards and should be cleaned up immediately. If a spill should occur, the general procedure outlined below should be followed.
 - a. The person who caused the spill is responsible for the cleanup - unless that person has sustained an injury as a result of the spill.
 - b. Medical attention should be obtained for any person who is injured by the spill.
 - c. Notify all persons in the area about the spill, including the faculty research advisor.
 - d. Have all nonessential personnel leave the area of the spill.
 - e. Post warning signs or station someone to prevent the spill area from being entered.
 - f. If the spilled material is flammable, turn off all ignition and heat sources in the area.
 - g. Avoid breathing the vapors of spilled materials.
 - h. Leave on or establish exhaust ventilation.
 - i. If there is any uncertainty as to how the spill should be cleaned up, see your Research Director, or, if he is not available, a member of the Safety Committee, another faculty member, or the Environmental Safety Office (ext.4-4636).
 - j. Never turn a chemical spill over to an untrained person for cleanup. If assistance from the building janitors, maids, or other Physical Plant personnel is required, make certain that the work is carefully supervised.

- k. Anticipate spills and have cleanup supplies - paper towels, sponges, brushes, mops, etc. - available.
 - l. During the cleanup, wear the appropriate gloves and other clothing as well as glasses or goggles to provide personal protection.
2. Handling of Spilled Chemicals. If it is feasible, corrosive or toxic substances should be deactivated before a cleanup is attempted. The general guidelines given in Section [III D 2](#) and [IV L](#) should be followed for deactivating such materials.

For liquid spills adhere to the following general guidelines:

- a. Confine the spill to as small an area as possible.
- b. For inorganic acids or bases, use a neutralizing agent or an absorbent mixture, e.g., soda ash or diatomaceous earth. For small quantities of other materials, absorb the liquid with a nonreactive material, e.g., vermiculite, sand, or towels. Use care because the absorbent materials will give off vapors, or paper towels may be ignited as certain chemicals dry out in air. Commercial spill control agents and cleanup kits for various substances are available.
- c. Very large liquid spills can be flushed down with large amounts of water if this will cause no damage.
- d. Carefully remove any containers from the spill area and clean the outside of them completely.
- e. If the spilled material is volatile, let it evaporate and be exhausted by mechanical ventilation.
- f. Mop up the spill completely. Wring out the mop in a sink or a pail equipped with rollers.
- g. Clean all items, e.g., mops, before returning them to storage or before using them for other purposes.
- h. Dispose of residues resulting from the cleanup in an appropriate manner.

For solid spills follow the following rules:

- a. Sweep non-toxic spilled solids into a dust pan and place them in an appropriate waste disposal container.

- b. Toxic solids should be cleaned up with an efficient vacuum cleaner approved for the material involved.
- c. Always clean equipment used in the cleanup carefully when the operation is finished.

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III. HANDLING OF CHEMICALS (GENERAL)

A. General

You should recognize that almost all chemicals are potentially dangerous if improperly used and that strict safety precautions should always be adhered to when handling them. Before a chemical is ordered from an outside supplier or checked out of the stockroom, you should be certain about the following points: (1) The chemical is definitely needed for the work you are attempting to accomplish, (2) The possible hazards associated with storage and use of the chemical have been assessed (refer to [MSDS](#) Files) and the information and facilities for its proper handling are available, (3) The proper reagents and equipment for detoxifying and cleaning if it is accidentally spilled are available, (4) The chemical can be disposed of safely without endangering the health of others. It is essential that professional chemists with prior knowledge of the chemical recognize that they have the responsibility of disposing of it safely themselves or delegating the responsibility to those persons familiar with hazardous substances.

You should recognize that this Manual will not provide you with enough detailed information for handling all of the chemicals which you will encounter. However, it is hoped that the following general rules will be helpful and will serve as a stimulus for you to seek additional information. A bibliography of reference books on laboratory safety is found in Section V. These books may be found in the School of Chemistry Reading Room (Room 2-31).

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B. Labeling for Identification

All containers of chemicals and other materials must be labeled properly so that a stranger will have sufficient information to handle the substances safely. When receiving new chemicals, make certain that the label is legible and has not been contaminated with chemicals which will cause it to fade or deteriorate. If the need arises, make a fresh label. When containers are being labeled for the first time, the label should contain at a minimum the following information: name of substance, date, unusual hazard information, and the name of the individual who prepared it if it is a special preparation. The stock of chemicals in the laboratory should be checked periodically to make certain the labels are in good condition. If a label is fading or becoming unglued so that it is likely to fall off, it should be

replaced immediately. **NEVER** place a new label on top of an old one; always wash off the old label completely before applying a new one.

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C. Storage and Transport of Chemicals

1. Storage. Chemicals may be stored in the laboratories in the area provided, but the number and quantity of chemicals on hand should be kept at a minimum, consistent with the efficiency of the operation. Storage of chemicals on bench tops or in hoods should be avoided. Storage trays or secondary containers should be used to minimize spreading of material in case of a break or leak.

Storage areas should be well-ventilated. One should exercise good safety practices when storing chemicals. Two chemicals that are likely to react with each other should not be stored in close proximity. This is especially true if the chemicals would react explosively, (e.g., certain organic solvents and strong oxidizing agents), or react to form a toxic product, (e.g., KCN and acid). Pyrophoric materials or materials which are highly reactive with water should never be stored near flammable liquids. See [Section III I](#) for further information on pyrophoric materials.

Especially volatile or thermally unstable chemicals may be stored in the refrigerator. All refrigerators which are used for chemical storage must be of the explosion proof type or must have had all devices that can cause a spark moved outside. All containers of volatile material must be tightly sealed before being placed in a refrigerator. When possible, store all liquids in the refrigerator in screw-cap bottles with Teflon liners in the caps. Food should **NEVER** be stored in a refrigerator which is being used for chemical storage presently or in the past.

Toxic chemicals, e.g., carcinogens, should be stored in secured, well-ventilated areas and only those persons who are authorized by Research Supervisors should have access to them. An inventory should be carefully maintained on these chemicals by the Research Supervisors. Refrigerators or other areas where toxic chemicals are being stored should be also labeled and the toxic material should be removed as soon as it is practical to do so.

The possession and storage of certain materials are regulated by state or federal agencies. All legal requirements concerning the ordering, handling, and storage of any such substances should be complied with. Chemicals should never be stored or handled near writing desks. Stored chemicals should be inspected regularly for leakage due to container corrosion, decomposition, and label deterioration. Radioactive chemicals must be handled, stored, and disposed of according to the procedures which are developed by the Georgia Tech Radiological Safety Office.

2. Transport. All chemicals should be transported with the utmost care. If more than one or two items are to be transported, appropriate laboratory carts and the freight elevator should be used. Know what to do in case of a spill before starting to transport any chemical. Do not transport unprotected glass bottles of chemicals in the halls, stairwells, or either elevator. Instead carry bottles in rubber or metal safety pails.

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D. Disposal of Waste or Excess Chemicals

1. General. Information from the Environmental Safety Office concerning waste chemical disposal is dispensed frequently. Please keep abreast of this and all new procedures.

Ultimately the responsibility for disposal of waste substances rests with the workers who order and use them. Hazardous, toxic chemicals are best disposed of by professional chemists. Such substances should be converted into less hazardous ones in the laboratory prior to disposal. For example, strong carcinogens should be oxidized in solution before disposal and highly reactive substances, e.g., active metals, metal hydrides, etc., should be deactivated under controlled conditions. The reference book, "Prudent Practices for Disposal of Chemicals from Laboratories," provides much helpful information.

Toxic, malodorous, or lachrymal (tear producing) chemicals should never be disposed of by pouring them down the sink drain. The sink drains are interconnected; a substance which is poured in one drain may be detected as a vapor in another laboratory. However, this problem may be minimized if all drain traps, including floor traps, are kept filled with water.

2. General Suggestions for Waste Disposal. The following are general suggestions for disposal of non-hazardous water-soluble chemicals and other refuse:
 - a. Acids and alkali in small quantities and in low concentrations may be disposed of in laboratory sinks. Salt solutions and water-soluble organic compounds may be disposed of in the same manner.

All water-soluble materials disposed of in sinks should be washed down with large volumes of water to prevent clogging of the drains and corrosion of the pipes.

- b. Chemicals which react violently with water should never be dumped into the sinks. First, neutralize these chemicals with the appropriate

agents, and then wash them down the sink with water if not prohibited due to other considerations.

- c. Higher-boiling, water-insoluble organic materials (hexane, etc.) should not be poured into sinks. Notify the Environmental Safety Office at Ext. 4-4635 for pick-up.

- d. Small quantities of relatively non-toxic, low-boiling, water-soluble organic materials may be allowed to evaporate in flame-free, well-ventilated hoods. Volatile materials should never be poured into the sink.
- e. Information on the proper means of disposal of larger quantities of waste solvents should be obtained from the Environmental Safety Office (Ext. 4-4636).
- f. Non-hazardous, water-insoluble solids may be placed in the trash cans in the laboratory after being packaged in plastic bags.

Make certain that all solids, (e.g., chromatographic materials), are free of moisture or organic solvents before placing them in the trash cans. If the solid is contaminated with a flammable liquid, a fire could easily result during the ensuing disposal of the refuse. The trash cans are used for disposal of paper and other flammable material. Therefore, never place any solid, e.g., an active hydrogenation catalyst, which has the potential for ignition in the trash cans. No substances may be placed in the trash cans in closed glass or metal containers. In fact, all glass bottles or other containers which are being thrown away should be washed thoroughly and disposed in "sharps" containers. Be considerate of those persons who handle disposal of trash. Broken glass with sharp edges, glass rods, tubing, and pipets should also be placed in special trash containers that are marked "SHARPS."

- 3. Special Waste Problems. The Georgia Tech Environmental Safety Office can arrange for the disposal of hazardous chemicals if the need arises. Further information is available from the Director of the GT Environmental Safety Office at 404-894-4635 , [GT Environmental, Health and Safety website](#).

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E. [Compressed Gas Cylinders](#)

- 1. General. A Compressed gas is defined by the Interstate Commerce Commission as "any material or mixture having the container either at absolute pressure exceeding 40 pounds per square inch at 70°F, or an absolute pressure exceeding 104 psig at 130°F, or both; or any liquid flammable material having a Reid vapor pressure exceeding 40 psig absolute at 100°F."
- 2. General Rules

- a. Cylinders may not be filled except by or with the consent of the owner.
- b. Each cylinder must bear a proper caution label and carry a legible identification mark.
- c. When returning empty cylinders, valves should be closed and protective caps replaced.
- d. Never attempt to repair or alter a cylinder.
- e. Never repaint a commercial cylinder. To do so may destroy its identifying paint code.

3. Specific Rules

- a. Cylinders should be stored in a definite, assigned location.
- b. Cylinders that cannot be easily carried or controlled should be transported on a special cylinder cart.
- c. Cylinders should be transported with cap in place and should never be transported on the passenger elevator.
- d. All cylinders must be tightly secured to a wall, bench, or heavy table with a chain or other approved retainer while they are in use and during storage.
- e. Compressed gases should be handled only by experienced and properly instructed persons.
- f. Always be sure that the proper regulator is used. Never force connections that do not fit readily.
- g. Open cylinder valves slowly. Avoid the use of a wrench on valves equipped with handwheels.
- h. Consult reference material for use of specific cylinders.
- i. Keep the quantity of flammable gases in the laboratory at the minimum consistent with current requirements. Do not store unused cylinders in the laboratory.
- j. Cylinders containing corrosive or toxic gases should be opened only in the hoods.

- k. Avoid keeping gas cylinders in the laboratory for extended periods. Demurrage charges mount rapidly and soon become greater than the cost of the cylinder content.

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F. Handling of Flammable Liquids

Most organic liquids are flammable in the sense that the vapors will burn or explode under the proper conditions. By definition in the National Fire Codes: A "flammable liquid" shall mean any liquid having a flash point below 140°F and having a vapor pressure not exceeding 40 lb./sq. in. absolute at 100°F. "Flash Point" shall mean the minimum temperature in degrees Fahrenheit at which a flammable liquid will give off flammable vapor as determined by a specific test procedure and apparatus.

Flammable liquids present serious fire and explosion hazards when stored or handled improperly. The following rules should be observed:

1. Large quantities of flammable liquids (drums, cans, and bottles) should be stored in the Solvents Storage Area (i.e. external building under control of departmental stockroom).
2. Outside storage cabinets for flammable solvents should be used whenever possible.
3. Non-glass containers (either plastic or metal) should be used whenever possible, but it should be recognized that some solvents will dissolve certain plastics.
4. Solvents that are not anhydrous or of reagent purity should be stored in safety cans with flash screens.
5. Do not transport flammable liquids in open containers.
6. Keep as little flammable liquid in laboratories as is possible, consistent with normal laboratory work. Only solvents used in active laboratory programs should be stored in the laboratory.
7. The maximum amount of flammable liquid (of all kinds) stored in glass in any one laboratory is limited to 5 gallons for laboratories of 250 sq. ft. or less, and to 10 gallons for all larger laboratories. (Gallon glass bottles of liquids must also be kept in metal or plastic safety pails.) The maximum amount of flammable liquid stored in metal containers should normally not exceed 5 gallons of any one solvent in each laboratory.

8. For equipment containing flammable liquids, consideration should be given to providing a leak proof catch pan to confine accidental spills or leakage.
9. Do not evaporate volatile organic solvents on a hot plate, except in a hood. Keep flammable liquids away from Variacs, heat guns, and other sources of sparks.
10. When flammable liquids are being transferred in air, provide adequate ventilation of the area to prevent buildup of an explosive mixture with the air.
11. Drums or metal vessels from which flammable liquids are being drained should be grounded and bonded to the receiver.
12. In areas where there is a possibility of flammable vapors, electrical equipment must be explosion-proof.
13. Vent lines from equipment should be directed outside or into a hood.

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G. Common Chemicals with Sufficient Toxicity to Require Control of their Vapor Level

The [American Conference of Governmental Industrial Hygienists](#) (ACGIH) produces annually listings of Threshold Limit Values (TLV) and Short Term Exposure Limit Values (STEL) for common chemicals used in laboratories and elsewhere. These values are defined as follows:

TLV -- Time weighted average concentration for a normal 8 hour work day to which nearly all workers may be repeatedly exposed without adverse effect.

STEL -- The maximum concentration to which workers can be exposed for periods up to 15 mm. Such exposures should be limited to no more than four per day with periods of each at least 60 mm between exposures; the total time-weighted exposure per day should not exceed the TLV value.

Assuming “typical” general ventilation in a laboratory (4 to 6 changes of air per hour), many Industrial Hygienists recommended that auxiliary local ventilation (a hood or its equivalent) be used for any volatile material with a TLV of 50 ppm (part per million) or less. A copy of the [current ACGIH list](#) is available on-line. Work with these compounds in a laboratory should be performed in such a way that the materials do not come in contact with the skin and the vapor above these materials is removed from the laboratory atmosphere with an auxiliary local ventilation system such as a hood. Note that the absence of a compound from this

list does not necessarily mean that the compound is relatively non-toxic. Consult appropriate sources ([MSDS](#) files) for information on compounds not on the list. Also note that for some of the compounds listed, STEL values have not been established. As a rough “rule-of-thumb,” the evaporation of about 5 g of a low molecular weight material into 1000 ft³ of static air will give an airborne concentration of material in the range of 50 ppm.

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H. Drying of Solvents

This procedure often is one of the more hazardous laboratory operations. The problem is due to the flammable nature of most solvents and reactivity of drying agents. If highly effective dehydration is desired, the drying agent must be very reactive with water and often is pyrophoric. Separation of dehydrated solvent from the reaction mass then may require a distillation step, which can be hazardous if unstable sludges are allowed to form and overheat.

A number of serious explosions and fires have occurred during purification of solvents. During any drying operation using highly reactive reducing agents or distillation steps, a vigil should be maintained in the interest of laboratory safety.

Strong reducing agents (g., LiAlH₄) are often used to effect maximum dehydration of solvents. Their use must be limited, however, to solvents with which they will not react. Examples of these reactive compounds are lithium aluminum hydride, sodium borohydride, calcium hydride, magnesium hydride, sodium dispersions, DehydriteH, a commonly available drying agent, is magnesium perchlorate which can react violently with certain organic materials. Many others decompose spontaneously when heated with strong bases, sodium hydroxide, sodium alkoxides, to temperatures above 200-250°C.

In practice, it is best to avoid adding the drying agent to the solvent in excess of the amount needed for complete water removal. The mixture is stirred for several hours or allowed to stand until hydrogen evolution ceases. The container must be vented during this period to prevent rupture or stoppers being blown out. Separation of dried solvents by vacuum distillation is preferred to atmospheric pressure distillation because of the lower pot temperatures required. Some of the complex metal hydrides used have low decomposition temperatures and can explode violently when overheated.

Many literature procedures call for the drying of certain solvents, ether, tetrahydrofuran (THF), etc., with lithium aluminum hydride. However, because of the hazard associated with the use of this material, it should be used only if you are authorized to do so by your Research Supervisor.

1. General

- a. For solvents to remain anhydrous, containers should be tightly sealed. Ordinary caps breathe over a period of time and allow air and moisture to enter. Storage in a dry box does not necessarily provide full protection against this problem.
- b. Solvents stored over sodium ribbon will not remain anhydrous if allowed to breathe. However, the caps should not be tightly closed during the drying period because pressure may increase dangerously.
- c. Distillation conditions should be kept as mild as possible and should not proceed to the point where the sludge is not very fluid. Concentrated systems approaching an oxidant-reductant balance should be avoided. It should be recognized that ethers and certain other chemicals form peroxides and should therefore never be distilled to dryness. (See [Section IV K on Peroxidizable Solvents](#).)
- d. Sample sizes of highly flammable solvents, ethers, should be kept to a minimum. One-liter batches are a reasonable maximum for laboratory use.
- e. Safety equipment should be used in the drying and distillation operations. Safety shields are recommended for all distillations, and the more hazardous systems should be confined to restricted areas, hoods.
- f. Special caution must be taken when refluxing solvents with a drying agent. Condensers may break (especially under vacuum) allowing water to enter the boiling flask. Hood sashes should remain closed and blast shields used when possible.

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I. Pyrophoric Materials

The term “pyrophoric materials” as used herein will mean any material which, upon exposure to air, has the possibility of spontaneously igniting either immediately or after standing for a short period of time. Such materials are usually liquids and include the lower molecular weight aluminum, zinc, and boron compounds including the alkyls, alkyl hydrides, or alkyl halides. Pyrophoric solids are also known, such as: lithium and sodium aluminum hydrides and fine dispersions of metals such as Li, Na, K, Zn, Mg, Al, etc.

1. Properties. Since properties vary widely, it is the responsibility of the individual concerned to obtain all available background bearing on the particular material being used. Some materials (such as trimethylaluminum) are pyrophoric except under unusual circumstances.

However, surface area exposed, temperature, and agitation are important factors. A given compound may not ignite immediately when exposed to air, but shaking or agitation of the surface may induce flammability. The aluminum-containing pyrophoric materials are also extremely active toward water. Many are explosive when contacted with water.

The tendency of liquid materials to ignite is considerably diminished by dilution with inert solvents. At 15-25% concentrations in hydrocarbons they usually become non-pyrophoric, but still react with oxygen or moisture at a moderate rate. The more volatile the solvent, the more dilution is required to prevent ignition. It should be remembered, however, that if ignition does occur, the presence of the solvent will increase the danger.

2. Storage. Large quantities of pyrophoric materials should be stored in metal containers and kept in a cool, dry area away from cylinders of oxygen or other oxidizing agents. In the laboratory, small amounts maybe kept in almost any container that can be kept tightly closed. The container should be stored in a nitrogen filled box to prevent a fire in the event of an accidental opening. When glass containers are used, always keep them in a supplemental metal container. Use a non-flammable stabilizing material such as vermiculite, dry sand, or glass wool between the metal and the glass container. Special attention should be given to preventing ground glass stoppers from becoming frozen. "Sanitab" stoppers provide satisfactory substitutes in most cases.

The prime factor in manipulation of pyrophoric materials is prevention of all atmospheric contact. This should be kept in mind continually and appropriate procedures devised. Most storage cylinders are fitted with a dip tube connected to one of a pair of valves. Application of nitrogen pressure through the other valve will force the material through tubing into a container that must be thoroughly dried and flushed with nitrogen beforehand. Other transfers, involving smaller amounts, are best carried out in the nitrogen filled box.

In handling small amounts of pyrophoric material for reactions or tests in the laboratory, a syringe can often be used, injecting the compound directly into the apparatus through a rubber serum cap. For this procedure, the small exposure at the tip of the needle is negligible, although for very active materials it is advisable to cap the needle with a small rubber stopper. For use of larger amounts in the laboratory, dropping funnels or flasks may be charged in a nitrogen filled box. These are stoppered and carried to the apparatus. With a vigorous flow of nitrogen issuing from the apparatus the container may be quickly unstoppered and the flask or funnel joined to the set-up.

When carrying out any reaction involving these reactive materials, possible accidents should be anticipated. If any appreciable quantity of material is involved, a metal pan or other container should be placed under the apparatus to contain the reactants, should breakage occur. Flammable substances should be removed from the vicinity of the experiment so as to avoid spread of the fire from the pan. DO NOT HAVE EXTRANEIOUS BOTTLES OF OTHER MATERIAL STORED IN THE HOOD USED FOR THESE REACTIONS.

For the aluminum - and sodium - containing materials, thought should be given to use of coolants other than water. The presence of water in the immediate vicinity of the experiment should be avoided.

3. First Aid. Most pyrophoric materials cause severe burns when they come in contact with the skin. Even dilute solutions will result in burns because of reactions with moisture and oxygen on the skin, even though ignition does not occur. First Aid consists of a prompt removal of the material by copious flushing with water (do not use alcohol or acetone) and removal of contaminated clothing. The burns should then be treated as thermal burns. Do not use a fire blanket to smother a burning clothing fire unless a safety shower is not available. The blanket does not cool, smoldering clothing will continue to burn, and chemicals on the skin or clothing will remain reactive.

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J. Selection of Gloves for Skin Protection from Toxic or Corrosive Materials

It is extremely important that care be exercised in avoiding contact of the skin with toxic or corrosive materials. Proper gloves should be worn at all times whenever the potential for contact with toxic substances exists. Not all gloves provide equal protection against chemicals and glove materials should be selected on the basis of the material being handled and the particular hazard involved. Natural latex, neoprene, nitrile rubber, and polyvinyl chloride are commonly used materials for glove fabrication and each provides optimum protection for certain classes of compounds. These gloves may be obtained from the stockroom or outside suppliers. The following table provides information which will allow the selection of the type of gloves that will provide the best protection against a particular chemical. More specific information can be obtained from the glove manufacturer.

Resistance to Chemicals of Common Glove Materials

(E = Excellent, G = Good, F Fair, P = Poor)

Chemical	Natural Rubber (Orange latex)	Neoprene (Black w/red liner)	Nitrile (Cream)	Vinyl (Disposable)
Acetaldehyde	G	G	E	G
Acetic acid	E	E	E	E
Acetone	G	G	G	F
Acrylonitrile	P	G	-	F
Ammonium hydroxide (sat)	G	E	E	E
Aniline	F	G	E	G
Benzaldehyde	F	F	E	G
Benzene ^a	P	F	G	F
Benzyl chloride ^a	F	P	G	P
Bromine	G	G	-	G
Butane	P	E	-	P
Butyraldehyde	P	G	-	G
Calcium hypochlorite	P	G	G	G
Carbon disulfide	P	P	G	F
Carbon tetrachloride	P	F	G	F
Chlorine	G	G	-	G
Chloroacetone	F	E	-	P
Chloroform ^a	P	F	G	P
Chromic acid	P	F	F	E
Cyclohexane	F	F	*	P
Dibenzyl ether	F	G	-	P
Dibutyl phthalate	F	G	-	P
Diethanolamine	F	E	-	E
Diethyl ether	F	G	E	P
Dimethyl sulfoxide ^b	-	-	-	-
Ethyl acetate	F	G	G	F
Ethylene dichloride	P	F	G	P
Ethylene glycol	G	G	E	E

Ethylene trichloride ^a	P	P	-	P
Fluorine	G	G	-	G
Formaldehyde	G	E	E	E
Formic acid	G	E	E	E
Glycerol	G	G	E	E
Hexane	P	E	-	P
Hydrobromic acid (40%)	G	E	-	E
Hydrochloric acid (conc.)	G	G	G	E
Hydrofluoric acid (30%)	G	G	G	E
Hydrogen peroxide	G	G	G	E
Iodine	G	G	-	G
Methylamine	G	G	E	E
Methyl cellosolve	F	E	-	P
Methyl chloride ^a	P	E	-	P
Methyl ethyl ketone	F	G	G	P
Methylene chloride ^a	F	F	G	F
Monoethanolamine	F	E	-	E
Morpholine	F	E	-	E
Naphthalene ^a	G	G	E	G
Nitric acid (conc.)	P	P	P	G
Perchloric acid	F	G	F	E
Phenol	G	B	-	E
Phosphoric acid	G	E	-	E
Potassium hydroxide (sat)	G	E	-	E
Propylene dichloride ^a	P	F	-	P
Sodium hydroxide	G	G	G	R
Sodium hypochlorite	G	P	F	G
Sulfuric acid (conc.)	G	G	F	G
Toluene ^a	P	F	G	F
Trichloroethylene ^a	P	F	G	F
Tricresyl phosphate	P	F	-	F
Triethanolamine	F	E	E	E

- a. Aromatic and halogenated hydrocarbons will attack all types of natural and synthetic glove materials. Should swelling occur, the user should change to fresh gloves and allow the swollen gloves to dry and return to normal.
- b. No data on the resistance to dimethyl sulfoxide of natural rubber, neoprene, nitrile rubber, or vinyl materials are available; the manufacturer of the substance recommends the use of butyl rubber gloves.

Other general rules about the use of gloves:

1. Gloves should be inspected regularly for discoloration, punctures, and tears.
2. Before removal, gloves should be washed appropriately. (Polyvinyl chloride gloves are permeable to water.)
3. Gloves should be replaced periodically, depending on the frequency of use and permeability to substances handled.
4. Insulated gloves (such as aluminized asbestos and terry cloth) should be used when handling hot objects.
5. Specialized gloves are available for certain specific jobs. Information on these may be obtained from glove manufacturers.

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K. Hood Operations

As has already been indicated, laboratory fume hoods are extremely important safety devices which, when operated properly, afford protection from exposure to chemical fumes and particles which are potentially hazardous to the health. Several factors that influence the efficiency of the operation of a hood are: laboratory air supply, face velocity, work practices, and equipment placement. The following standards and operating practices are prescribed to ensure satisfactory hood operations.

1. Air Supply. The building ventilation system as it is normally operated provides an air supply which is adequate for satisfactory operation of the hoods. However, one should always be sensitive to changes in the operation of the ventilation system. In the event of a power failure not only do all the hoods cease to operate but the building ventilation system would go out too. If the power goes off, the liberation of all substances in

the hood should be ceased and the hood doors should be completely closed so that the natural draft of the hood flow will remove noxious vapors. If the power outage lasts for more than a few minutes, the building should be evacuated. The main blower fans are often cut off by Physical Plant personnel. This may have a significant affect on the hood performance. The use of the hoods is not recommended whenever these input air fans are off.

2. Face Velocity. The following procedures should be followed in using and conducting experiments or other work in the hoods.

- a. The hood fan should be left on around-the-clock if a hood contains hazardous material that is being vented or might vent. Otherwise, the hood fan should be turned off when the hood is not in use. However, when a single fan serves several hoods, do not shut the fan down before checking with others. Never assume that the hood fan is on without checking to make sure. With experience one can “feel” the draft from the hood, but more specific measures should be followed to insure that it is operating properly. The red lights near the hood fan switches indicate that the switch is on, but not necessarily that the fan is actually operating. However, if the bulbs for these lights blow out, they should be replaced. Many hoods are now equipped with gauges which should be checked to ascertain that the hood is on. If the hood is not equipped with a gauge or you have reason to question that the gauge is operating properly, it is a simple matter to determine if the hood is operating by reducing the hood opening to a few inches and striking a match, blowing it out, and holding it a few inches in front of the hood to see the direction of smoke flow. Most hoods have movable panels in the back which control the inflow to the duct. Check these carefully to make sure they are open and properly positioned. If the hood is not working, this should be reported so that it can be repaired immediately. Put a sign on any non-functioning hood to warn others not to use it.
- b. Avoid creating strong cross drafts in front of the hood opening. This can allow contaminants to be pulled into the room. Wind blowing in a window, walking by the hood face, heat gun operation, etc., could create such drafts.
- c. Keep the hood closed when it is not in use.
- d. Arrange all equipment and conduct all transfers as deep in the hoods as is conveniently possible. Most hoods have a yellow line painted about 6 inches from the front of the hood. All operations should be performed behind this line for safe use of the hood. Vent equipment toward the back or in an upward direction.

Rupture disc and safety relief valve arrangements should include extensions leading through the top of the hood into the intake duct as close to the fan as possible. Secure the free end of each extension tube.

- e. Flammable materials should not be vented into the hood at a high enough rate to create a flammable mixture in the exhaust system.
- f. Never remove doors from hoods. Whenever possible, keep the door between yourself and the operation in progress, as the door will provide you with protection from splattering chemicals, etc. However, although the hood doors are made of laminated glass, they will not afford protection from powerful explosions. Therefore, safety shields and other equipment should be set up in the hoods just as would be done if the experiment were conducted on the open bench.

The hood doors should be moved very carefully because the rollers at the top can easily get off the track. If this happens, the inside doors will fall into the hood and perhaps cause a significant amount of damage. The major reason that the doors become untracked is that dirt, small sticks, matches, paper, etc., collect in the track that the bottom of the door slides along. Keep an eye on these tracks and clean them out periodically. Have the hood doors repaired if they don't move properly.

If the hood is equipped with a "Sash" door, KEEP THE SASH DOOR CLOSED AT ALL TIMES. In order to improve air velocity on older hoods, many hoods in the Boggs Building are equipped with SASHES, which improve air velocity. Operating the hood with the sash open will decrease the air velocity below current safety standards.

- g. If the hood should stop operating for any reason, immediately cease venting of hazardous materials and close the hood doors until it can be repaired. If any danger exists because of the hood failure, inform others in the laboratory and in other parts of the building and put a warning sign on the hood.

- 4. Placement of Equipment and Chemicals. HOODS SHOULD ALWAYS BE KEPT CLEAN AND NEAT. One should place only those items in the hood which are to be used for the experiment which is being performed. When one is finished with an item, e.g., a solvent bottle, a gas cylinder, etc., it should be removed from the hood. There are several important reasons for keeping the hood clean and free of extraneous items. Among these are: (1) Bottles and other large objects in the hood can profoundly influence the air flow and hood efficiency, (2) If a fire or explosion occurs

in a reaction vessel, this may break reagent and solvent bottles which are in the hood thereby increasing the danger, and (3) workers are more likely to use the hoods safely if they are not allowed to become cluttered.

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IV. PRECAUTIONS FOR SPECIFIC CHEMICALS

A detailed discussion of many hazardous laboratory materials will be found in the reference, "Prudent Practices for Handling Hazardous Chemicals in Laboratories."

A. Metal Hydrides

1. Properties. Metal hydrides and complex metal hydrides are reducing agents. These compounds vary so widely in physical properties, reactivity, and thermal stability that a person working with a particular hydride should obtain all available information on its properties and become thoroughly familiar with proper procedures for handling it. One should be thoroughly cognizant of potential dangers when using the material as well as be knowledgeable in dealing with dangers which might arise.

The thermal decomposition temperature of metal hydrides may vary from as much as 300°C to below 0°C. Some of these hydrides are spontaneously flammable with even dry air and certainly with oxygen gas; others, while air stable, may react violently with water. Still others, though, are stable both to oxygen and to water. Some hydrides are known to decompose explosively with only traces of oxygen or moisture. One should always remember, however, that while a hydride may not be spontaneously flammable with air, any decomposition will evolve hydrogen creating a potentially flammable condition and the possibility of an explosion since there is a wide explosive limit for hydrogen-oxygen mixtures.

2. Storage. The type of storage for any particular metal hydride will be dictated by its physical and chemical properties. Those hydrides which are very thermally stable, such as NaH or LiH, can be stored in sealed containers under an inert atmosphere such as nitrogen, argon, etc. Storage of hydrides under inert solvents, preferably those with a high flash point, will help protect against exposure. Hydrides such as LiAlH_4 can be stored in sealed containers provided plastic liners are available.
3. Handling. Metal hydrides should be handled in an inert atmosphere box (dry box) unless definite information indicates the hydride can be safely handled in other equipment and under other conditions. Direct contact of the skin with hydrides which normally react with water will result in both a chemical and thermal burn. Initial experiments with all hydrides should

be carried out with small quantities of reagents. Experiments carried out under a nitrogen atmosphere and in apparatus vented through a nitrogen bubbler will avoid exposure and pressure buildup. Addition of LiAlH_4 to diethyl ether in the open air has been known to result in explosions and fires due to the LiAlH_4 sparking at the mouth of the ether container.

4. First Aid. In the event of accidental contact of a metal hydride with the skin, brush off any gross amounts of loose solids; then flush with water until all reaction has stopped and any residual chemicals have been flushed away. Any burns should be treated as thermal burns. Contaminated clothing should be removed immediately.

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B. Sodium and Other Alkali Metals

1. Hazards. The principal hazards involved in working with alkali metals are: (1) explosive reactions with moisture, (2) caustic burns, and (3) fires. To minimize these hazards, it is important that these materials be stored in such a manner that they will not come in contact either with water or with the atmosphere.
2. Storage. Relatively large quantities of the metals may be safely stored in clean, rust-free metal containers that have air tight lids. Rusty containers are to be avoided since alkali metals will react vigorously with the rust. If only small amounts of these metals need to be stored, they may be placed on a clean metal or glass container and covered with a layer of dry "Nujol" or other dry inert hydrocarbon. If a glass container is to be used, it should be protected by placing it in an outer metal container. This will retain any spillage that would occur should the glass container break.
3. Handling. Eye protection must be worn at all times when handling these metals. Never allow contact of the bare skin with these metals. The molten alkali metals constitute a special safety problem because of the possibility of thermal burns as well as other hazards which are considerably enhanced. Approved safety goggles are required. Complete skin and eye protection must always be used when working with larger quantities of these molten substances.
4. First Aid. Burns produced by alkali metals are of the same nature as caustic burns. Gross amounts of the metal should be carefully and quickly removed and the area washed immediately with large volumes of cold water. Treatment may then be the same as for caustic burns.

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C. Mercury

1. Hazards. Mercury and its compounds are very toxic materials and tend to accumulate in the system with repeated exposure. Poisoning may occur by direct absorption through the skin or through inhalation, particularly since mercury itself is a slightly volatile liquid. The degree of air saturation with mercury vapor increases with temperature. Thus it is imperative that all mercury spills be thoroughly cleaned up and that even tiny droplets of the material do not accumulate the sinks, traps, clothing, and crevices.
2. Handling Procedures. Good ventilation must be present in a room when mercury is to be used or stored. Every precaution should be taken to prevent spillage of mercury, but if it is spilled, it must be picked up immediately. Particular attention should be given to small cracks and crevices as well as clothing. Various procedures are recommended for picking up mercury spills. A simple suction flask, fitted with a rubber tube and medicine dropper tip, will assist greatly in the picking up of spills. A mercury vapor respirator mask should be worn while cleaning up mercury spills. Ask the Environmental Safety Office to check the area with a mercury vapor monitoring device when you have completed a cleanup of spilled mercury. If mercury is still present, repeat the process.

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D. Chlorine

1. Hazards. Chlorine, a greenish-yellow gas, has a pungent, irritating odor, is heavier than air, and hence, seeks ground level when it is present in the atmosphere. While not combustible in air, it reacts violently with many substances and may cause fire or explosion when in contact with those substances. Exposure to the skin causes severe burns and blisters. Inhalation can destroy lung tissue causing the lungs to fill with water. Even in low concentrations it promotes low grade respiratory ailments, throat irritations, and coughs.
2. Handling Procedures. Chlorine cylinders should be stored in a cool, dry area and be protected from extreme temperature changes. Heat should never be applied to containers in order to increase the discharge rate. When using the gas, the area should be well ventilated. Water should never be used on a chlorine leak.

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E. Bromine

1. Hazards. Bromine is a very corrosive liquid that is quite volatile and gives rise to deep, penetrating skin burns which are very persistent and slow to heal. It attacks not only the skin but eye tissues and various mucous membranes much as does chlorine. It is a fire hazard since it may produce violent reaction with organic matter such as excelsior, sawdust, etc.
2. Handling Procedures. Bromine should always be stored in a cool place in glass bottles stoppered with glass stoppers. It should be kept out of direct rays of the sun, away from potential fire hazards, and from organic or easily oxidizable substances. Accidental spillage of bromine on the skin should be washed immediately and thoroughly with copious amounts of water.

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F. Amines

1. Hazards. Organic amines are gases, liquids, or solids, depending usually on the size and molecular weight. They have a fishlike odor depending upon their concentration in the air. Many amines are readily absorbed through the skin as well as by inhalation of the vapors or dust. Lighter amines, such as the methyl amines, are flammable compressed gases and must be kept from heat and open flames. Methyl amines, in particular, are irritating to the lungs and may cause burns to the skin. They also may cause an explosion upon direct contact with mercury.
2. Handling. Amines should always be used only in well ventilated areas. Exposure to the skin should be avoided by using proper gloves and other protective equipment.

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G. Peroxides

1. Hazards. Peroxides are relatively unstable compounds that are usually strong oxidizing agents; they differ widely in their characteristics. Since they represent a major degree of hazard, persons working with or handling these substances should obtain all available background on the particular peroxides being used. Many peroxides will slowly evolve oxygen; the process may be accelerated by heat, light, shock, or contact with other substances - even dust. Solutions and solvents frequently generate peroxides upon standing and this presents problems (See [Peroxide Formation in Solvents, Section IV K](#)). Organic peroxides, in particular, may be quite heat-, shock-, or pressure-sensitive and will detonate at times if the proper precautions are not observed. Though metal peroxides and hydrogen peroxide are not in themselves flammable, the organic peroxides are definitely flammable and will burn vigorously in the open.

2. Storage. Peroxides should never be stored in locations where the temperature can exceed normal room temperature; in fact, many peroxides require refrigerated storage. Thus, peroxides should never be stored near hot plates, Bunsen burners, ovens, or other heat sources. The storage room should be well ventilated so that temperature buildup does not occur. For many peroxides (such as hydrogen peroxide), the container must be able to “breathe” so that pressures do not develop upon standing. Too large amounts of these materials should not be stored in any one place except in properly designed, isolated sheds.

For the more shock-sensitive peroxides, the storage locations should be free of vibration and other mechanical shock. For example, it is hazardous to store peroxides in screw-cap jars in as much as known cases of detonation have occurred while tightening the screw cap on a container of benzoyl peroxide. Peroxides should be stored so that they do not come in contact with combustible materials and thus the original bags or fiber containers should be used for organic peroxides.

3. Handling. In handling **and** using peroxides, all the precautions outlined above should be followed. Being oxidizing agents, peroxides produce irritation of the skin that is sometimes severe. Protective equipment should be used as necessary to avoid contact with the skin or eyes. Experiments with peroxides should be affected with small quantities of reagents, using all precautions. If grinding or other friction is necessary, carry this out under a solvent which will minimize the danger. In general, one should never work with quantities of peroxides greater than 25 g; 1-2 g. quantities are more appropriate. A safety shield should always be used.
4. First Aid. In the event of accidental contact with the skin, remove the gross material with copious amounts of water. Then wash thoroughly with soap and water. If a peroxide contacts the eyes, immediate irrigation with large amounts of water should be instituted. Medical care should then be obtained.

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H. Dry Ice and Liquid Nitrogen

1. Hazards. Dry ice and liquid nitrogen can inflict severe frost bite “burns” to the skin and to the eyes. Dewar flasks, which are used to contain liquid nitrogen, are fragile and must be handled with care.
2. Handling. Dry ice should never be carried with bare hands; gloves should always be used when handling this material. Both dry ice and liquid nitrogen require the same eye protection as do chemicals in general. Eye protection must be worn when handling either of the materials. The Dewar flask used for transporting and storing quantities of these

substances should be taped with electrical tape or equivalent before use. All operating instructions on the liquid nitrogen storage tanks should be fully observed. The greatest hazard associated with the use of liquid nitrogen or other low-boiling cryogenic liquids is that sufficient oxygen can be condensed out of the atmosphere into Dewar flasks, traps, and other equipment to cause explosions. Avoid conditions which may lead to buildup of liquid oxygen.

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I. Ethers

1. Hazards. Except for methyl ether, most organic ethers are liquids at room temperatures. Of these, the most hazardous are ethyl ether and iso-propyl ether which are extremely flammable. They have low flash points and low ignition temperatures and represent extreme fire hazards. Ethyl ether, as well as ethers in general, should be used in well ventilated areas. Prolonged standing of ether may result in the formation of peroxides in the ether. These can easily cause an explosion. Should it be suspected that ether contains peroxides, very careful handling should be observed since these peroxides can be very sensitive to shock or temperature changes. Never distill any ethers to dryness since this concentrates any peroxides that may be present. See [Section IV-K](#) for tests for the presence of peroxides.
2. Handling. Ethers should always be used in well ventilated areas. Flames, sparks, and hot objects (above 162°C) should be kept away from the area in which ethers are being used.

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J. Corrosive Acids

1. Hazards. Examples of these substances include sulfuric, hydrochloric, nitric, perchloric, and acetic acids. These are generally colorless liquids with sharp, penetrating odors. Some are strong oxidizing agents. Some, such as sulfuric and glacial acetic, are basically anhydrous. The major hazard is contact with body tissue, especially the eyes. Damage to the respiratory system can be severe should acid fumes be inhaled. Sulfuric, nitric, and especially perchloric acid must be isolated from organic materials and other reducing agents.
2. Handling. Strong acids should be diluted by pouring the acid slowly and with stirring into water; never pour water into a strong acid. When handling large quantities of acids, rubber gloves and goggles or a face shield must be worn; the use of work clothes and rubber aprons is also strongly suggested. It is sometimes necessary to fume a solution with

perchloric acid. The fumes of this acid can condense in hood vent systems resulting in a potential oxidation hazard with easily oxidizable materials which are present in the hood. Thus special care should be taken to scrub the perchloric acid vapors with water during such evaporations and special hoods are required. Sodium bicarbonate is effective in neutralizing any acid spills.

3. Preparation of Dichromate Cleaning Solution. It is occasionally necessary to use a strong oxidizing agent such as a mixture of a dichromate salt (sodium or potassium) and sulfuric acid for cleaning stubborn residual deposits on glassware. This chromic acid mixture may be stored and reused until it becomes green in color.

To prepare such a solution, one places approximately 10 g of sodium dichromate in a 2-liter beaker and adds just enough water to dissolve the salt completely. While the potassium salt may be used, the sodium one is preferred since it has greater water solubility. Then approximately one liter of concentrated sulfuric acid is added very slowly and gradually to the water solution to avoid splattering. The solution is most effective when hot. The solution may be stored in 1-liter, glass stoppered bottles.

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K. Peroxidizable Solvents

1. Hazards. Peroxides that form in common laboratory solvents have been one of the most frequent causes of laboratory explosions. Such explosions occur most frequently during a distillation or after a distillation has been completed and the equipment is being dismantled. Peroxidizable solvents should not be used in work with explosives. If their use cannot be avoided, concentration of peroxides in the explosive must be prevented as they may initiate detonation. Explosions have been known to occur during opening of bottles in which ethers have been stored. The following compounds are examples of common laboratory solvents that easily form peroxides:

Ethers

Dioxane
Tetrahydrofuran
(tetralin)
Diethyl ether
(decalin)
Di-isopropyl ether
hydrocarbons
Ethylene glycol dimethyl ether
cycloaliphatics

Hydrocarbons

Cyclohexene
Tetrahydronaphthalene
Decahydronaphthalene
Branched chain
Alkyl substituted

Diethylene glycol dimethyl ether

The rate of formation of peroxides is increased by exposure to light, heat, and air. It can be very rapid. For example, a detectable amount of peroxide has been noted in cyclohexene within one hour after distillation from sodium and storage in a glass- stoppered bottle.

2. Handling. Containers of peroxidizable materials should be clearly marked with adherent tape imprinted with the warning: "Warning -- May Contain Peroxides." These containers should be dated when received and again whenever opened to remove material and subsequent restorage. These should always be protected from heat, light, and air during the storage and, when once opened, the contents should be blanketed with nitrogen gas. Containers should be kept well closed.

Peroxidizable solvents should also be protected from heat, light, and air. Should solvents be exposed to air, they should be stored for no more than six months whereupon they should be either discarded or treated to remove any generated peroxides.

Before a peroxidizable solvent is used in an operation in which any contained peroxides would be concentrated, the solvent should be tested for peroxide content. The methods are described below. If peroxides are present, they should be removed by methods described below. During any distillation of a peroxidizable solvent, air should not be allowed to come in contact with the hot solvent. Whenever a solvent such as these is concentrated without first removing the peroxides, the residues obtained should be treated as explosive material.

3. Detection of Peroxides

Method A:

Dissolve a sample in glacial acetic acid. Add a few drops of a 10-15 percent solution of sodium iodide in acetone. If a color develops, peroxides are present. A yellow color indicates low concentration while a brown color indicates a high concentration of peroxide in the sample.

Method B:

Add a small sample of the material to be tested to an acidified 5-10 percent aqueous solution of sodium or potassium iodide. Agitate vigorously if the material does not dissolve. Add starch solution to the aqueous phase. If a blue color develops, peroxides are present. If the peroxide concentration is high, a yellow color may develop before the starch is added.

Method C:

Dissolve 1 mg of sodium dichromate in 1 ml of water in a test tube; add a drop of dilute sulfuric acid; and fill the tube with ether and shake. The formation of a blue color (perchromate) in the ether indicates peroxide.

4. Removal of Peroxides

Method A:

Peroxides can be removed conveniently by washing with aqueous solutions of reducing agents or by passing the solvent through a short column of ordinary activated alumina. This latter method is effective for both water insoluble and water soluble solvents (except lower alcohols). It has the advantage that no water is introduced into the solvent and small amounts of water which may be present in the solvent are removed. When not even traces of peroxide can be tolerated, it is convenient to have the solvent flow directly into the reaction vessel from the alumina column.

Care must be exercised in disposing of the activated alumina column after this operation. Experiments have indicated with peroxidized cyclohexene and dioxane that at least these peroxides are decomposed on the alumina rather than simply absorbed. To be safe, it is recommended that alumina which has been used for peroxide removal be flushed with or dumped into a dilute acid solution of potassium iodide or ferrous sulfate.

Method B:

Peroxide impurities in water-insoluble solvents (ethers, hydrocarbons, etc.) are easily removed by shaking with a concentrated aqueous solution of a ferrous salt. Frequently used for this is 60 g of ferrous sulfate, 42 ml of concentrated hydrochloric acid, and 85 ml of water. With some ethers, traces of aldehydes are produced by this treatment. If an ether of high degree of purity is required, it should be further shaken with 0.5 percent water solution of potassium permanganate, then with 5 percent sodium hydroxide solution and finally with water.

Method C:

Refluxing the peroxide-containing solvent over metallic sodium followed by direct distillation is perhaps the oldest method of peroxide removal. More recently, sodium hydride and lithium aluminum hydride have become popular for this use. Peroxide impurities are safely reduced to alcohols and remain behind after distillation as insoluble alcoholates. However, see [Section III H](#) for the hazards associated with the use of LiAlH_4 as a drying agent for solvents. This procedure can be used generally for hydrocarbons and ethers; however, one should remember a serious explosion can result when halogen containing solvents such as carbon tetrachloride, chloroform, "Perclene", "Triclene", etc., are heated with strong reducing agents such as free metals or their hydrides.

Obviously, organic reagents such as alcohols, phenols, acids, etc., which contain acidic hydrogen atoms which react with sodium cannot be purified by this method.

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L. Reference List of Common Hazardous Chemicals

1. Acid chlorides - Clean up with sand or NaHCO_3 .
2. Alkali metals or alkoxides - These react spontaneously with water or moisture as well as CO_2 . Therefore, do not use water or CO_2 extinguishers to quench flames; rather use dry soda ash (anhydrous Na_2CO_3 , or special extinguishing powders such as graphite with organic phosphate) or CaCl_2 with nonburnable plastic. For small fires, sand can be used.
3. Aromatic amines - These are toxic and readily absorbed through the skin. Immediate removal of spills on skin or clothing is to be effected by washing with water. Vapors also are toxic.
4. Halogenated amines and nitro compounds - These are toxic via inhalation or skin absorption. Remove spills with water.
5. Aromatic nitro compounds - As in 4 above.
6. Azides - These are explosive. Also, even dilute aqueous solutions of hydrazoic acid are toxic.
7. Carbon disulfide - This is extremely flammable and moderately toxic.
8. Caustic alkalis - These are toxic by virtue of corrosive action. Flush well with water.
9. Chlorosulfonic acid - In moist air, HCl and H_2SO_4 are formed. Avoid breathing fumes.
10. Cyanides and nitriles - These are toxic if inhaled, swallowed, or absorbed through the skin. Liquid nitriles and HCN are flammable. Use CO_2 extinguishers. Clean up cyanide spills with water but be sure to wear proper glove protection. Flush small amounts down the sink with copious quantities of water.
11. Ethers - These are quite flammable. Ethyl ether is slightly toxic; dioxane, ethylene oxide, and tetrahydrofuran are more toxic.
12. Halogenated hydrocarbons - These are quite toxic with cumulative and damaging effects on the kidneys and liver. Toxicity is high for methyl

iodide, methyl bromide, 1,1,2,2, -tetrabromoethane and 1,1,2,2-tetrachloroethane.

13. Hydrazine - This material is both quite toxic and flammable. Anhydrous hydrazine ignites at 23°C on a surface of iron rust and at 270°C on borosilicate glass. Use trays to hold glass bottles of hydrazine. Avoid stainless steel trays; rather use porcelain or polyvinyl chloride trays. Wash spills on skin with water.
14. Mercury and derivatives - These are extremely poisonous by inhalation or by contact on the skin. Spills must be cleaned with sulfur dust. Use trays to contain potential spills. See [section IV.C2 on mercury](#) for handling procedures.
15. Perchlorates - The greatest danger is that of explosion. Evaporation of acid solutions of perchlorates or perchloric acid must be performed in a special fume hood. Organic perchlorates in solution or as solids may explode. Heavy metal perchlorates are particularly explosive. Spills must be cleaned up, since soaking of perchlorate solution into other materials such as wood may cause spontaneous fires at a later time.
16. Peroxides - Seventy percent H₂O₂ may spontaneously explode. Organic peroxides such as benzoyl peroxide are flammable as dry solids and may be exploded by shock. Use trays for storage to guard against spillage. Use vermiculite or sand to clean up spills.
17. Heavy metals - Mercury and its compounds, antimony and arsenic compounds, Ni(CO)₄, silver compounds, lead compounds, and Cr(VI) compounds are variously toxic or explosive.
18. Benzene - Benzene is quite toxic. One should avoid inhalation and contact with the skin. All spills should be thoroughly cleaned up and the area washed with water.

For a list of "Highly Hazardous Chemicals", click here [Highly Hazardous Chemicals](#)

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M. Carcinogens

A number of chemical substances have been found either to produce carcinomas in test animals or to increase the probability of or susceptibility to this hazard.

[National Toxicology Program: Report on Carcinogens \(RoC\)](#)

The 11th RoC was released on January 31, 2005. The 11 th RoC contains 246 entries, 58 of which are listed as *known to be human carcinogens* and with the remaining 188 being listed as *reasonably anticipated to be human carcinogens*. Seventeen of the listings are new to the RoC. The new listings in the 11th RoC include lead and lead compounds, x- and gamma (g)-radiation , compounds found in grilled meats, and a host of substances used in textile dyes, paints and inks. The RoC also includes the listing of viruses for the first time including some human papillomaviruses, and Hepatitis B and C viruses.

Official Citation: Report on Carcinogens, Eleventh Edition; U.S. Department of Health and Human Services, Public Health Service, National Toxicology Program .

Known to be Human Carcinogens. (numbers refer to page numbers in the above link)

Bold entries indicate new or changed listing in *The Report on Carcinogens, Eleventh Edition*.

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Bold entries indicate new or changed listing in *The Report on Carcinogens, Eleventh Edition.*

General classes of compounds for which a carcinogenic risk exist include alkylating agents, arsenic and its compounds, beryllium and its compounds, cadmium and its compounds, chromium and its compounds, estrogenic and androgenic steroids, hydrazine and its derivatives, lead (II) compounds, nickel and its compounds, nitrogen mustards, (β -haloamines), N-nitroso compounds,

polychlorinated substances, polycyclic aromatic amines, polycyclic aromatic hydrocarbons, and sulfur mustards (β -halosulfides). Some recognized strong carcinogens are:

benzo[a]pyrene
3-methylcholanthrene
7, 12-dimethylbenz[a]anthracene
dimethylcarbamoyl chloride
hexamethylphosphoramide
2-nitronaphthalene
propane sulfone
many N-nitrosoamines
bis-chloromethyl ether
aflatoxin-B
aceylaminofluorene

Rigorous safety precautions should be followed when handling any of the specific compounds or classes of compounds in the two lists above. All new or unstudied compounds should also be handled with care until conclusive toxicity data are available. Information on the regulations for use of any of the carcinogenic compounds on the OSHA list above may be obtained from the Georgia Tech Environmental Safety Office before purchasing or working with them. The lists of known and suspected carcinogens are being updated constantly. Information on new additions to the lists should be obtained from the [Georgia Tech Environmental Safety Office](#) or [National Toxicology Program: Report on Carcinogens \(RoC\)](#).

Some general rules which should be followed when working with any carcinogen or suspected carcinogen are as follows:

1. Learn as much as possible about the toxicity of the compound and safe procedures for handling it before starting an experiment.
2. Always protect your hands and forearms by wearing either gloves and a lab coat or long gloves to avoid contact of toxic material with the skin. Dispose of contaminated garments or clean them in an approved manner before reuse.
3. Post warning signs, e.g., Caution: Cancer-Suspect Agent, in areas where carcinogens are being used or stored.
4. Transfer and work with toxic substances in an exhaust hood having a face velocity of at least 60 lfm to provide protection from toxic vapors and dusts.
5. After working with toxic materials, wash the hands and arms. Never eat, drink, smoke, chew gum, apply cosmetics, take

medicine, or store food in areas where toxic substances are being used or stored.

6. Use spill trays to contain spillage and avoid spreading of toxic substances.
7. Maintain complete laboratory notebook records on the use of all toxic compounds.
8. Trap large quantities of toxic vapors to avoid release of these vapors into the hood exhaust air.
9. Decontaminate all glassware and equipment before removing it from the hood for thorough cleaning.
10. Never dispose of broken, contaminated items without carrying out decontamination first.
11. Take measures to ensure that all cleaning and maintenance personnel are not exposed to carcinogenic materials.
12. Do not dispose of toxic substances by evaporation in a hood.
13. Decontaminate wastes containing toxic substances by chemical processes whenever feasible.
14. If chemical decontamination is not feasible, store wastes in tightly closed containers and label the containers clearly until appropriate measures for disposal are taken.
15. Follow the general procedures described in [Section II D for cleaning up spills](#), but employ other precautions suitable for the safe cleanup of the particular compound (s) involved.
16. If a toxic substance is used, have all plans for the experiments disposal of wastes, and handling of spills approved by your Research Advisor.

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V. SOURCES OF INFORMATION ON LABORATORY SAFETY

As has been noted previously, one will often need to seek information beyond what is found in this Safety manual before conducting specific experiments which may be particularly hazardous. Numerous pamphlets and books on laboratory safety are available. These and other works on laboratory safety may also be found in the Georgia Tech Main Library. Again, you are urged to seek as much information as possible about

proper procedures and possible hazards involved in working with materials before conducting experiments.

LISTING OF WEBSITE ADDRESSES USED IN THIS MANUAL

American Conference of Governmental Industrial Hygienists

<http://www.acgih.org/home.htm>

Chemistry-Accident-Incident-Report-Sheet

<http://www.chemistry.gatech.edu/docs/Chemistry-Accident-Incident-Report-Sheet.pdf>

GT Environmental, Health and Safety website

<http://www.safety.gatech.edu/index.php>

MSDS Databases

<http://www.usg.edu/ehs/library/msds.phtml>

National Toxicology Program: Report on Carcinogens (RoC)

<http://ehp.niehs.nih.gov/roc/toc10.html>

Official Citation: Report on Carcinogens, Eleventh Edition; U.S. Department of Health and Human Services, Public Health Service, National Toxicology Program

<http://ntp.niehs.nih.gov/index.cfm?objectid=32BA9724-F1F6-975E-7FCE50709CB4C932>

Worker's Compensation Claim (GT OHR site)

<http://www.admin-fin.gatech.edu/human/benefits/061100.html>

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National Academy Press, Washington, DC 1983

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For comments on this document, contact the Chair, Georgia Tech, School of Chemistry and Biochemistry, Safety and Security committee